GEOMORPHOLOGIC CHARACTERIZATION OF FOOT HILLS OF ARUNACHAL PRADESH USING REMOTE SENSING AND GIS TECHNIQUES

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Abstract:

Remote sensing and GIS have been increasingly used for geomorphological studies due to synoptic view and precise spatio-temporal data and image of earth surface features. RS GIS has been used to physiography and relief of the foothills of Papum Pare district of Arunachal Pradesh. The main earth surface parameter is slope, a derivative of height and distance is responsible for development and evolution of hillslope facets. Various geomorphic units have been delineated using satellite image in conjunction with DEM, aspect, drainage in the foot hills of Papum Pare District of Arunachal Pradesh. Drainage density reflects intensity of erosion in the area with uncohesive earth materials of Siwaliks and high intensity rainfall. Overall analysis indicates the rock types and structure especially in the Siwalik region control the Geomorphological characteristics of each identified Geomorphological units.

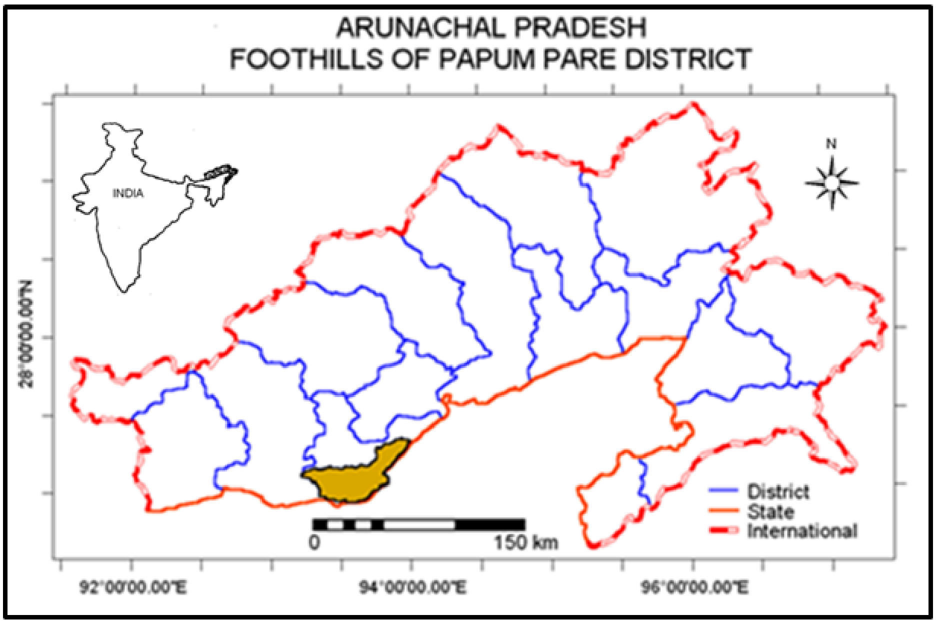
Introduction:

The developments on terrain analysis using GIS is being introduced recently and becoming more popular in Geomorphological studies. Further the development of remote sensing and availability of satellite image are providing more and precise spatio-temporal data for any area and thus helped in identifying geomorphic changes through time and space. Besides these, GPS has added another dimension in studying location and significance of earth surface features. All these advanced sources of information are deemed fit to help in studying influence of Geomorphological factors in any respect. Such advancement and incorporation of different technologies have provided opportunities for better understanding the theme and preparation of different target maps. The RS GIS capabilities have been utilised in the present study to understand the physiography and relief of the foothills of Papum Pare district of Arunachal Pradesh.

Location:

Papum Pare district has fifteen circles having total area of 2875 sq. km. The altitude ranges from below 100 m to 1300 m. Sagalee, Parang, Leporiang and Mengio circles are high hilly areas (between 1000 to 3000 m above m.s.l.) and the slope slowly lowers down towards the Assam state between which the foothills comes. The present study area includes the foothills of Papum pare district which falls under Taraso, Balijan, Banderdewa, Gumto, Doimukh administrative Circles and southern parts of Naharlagun, Itanagar and Kimin Circles with an area of 1411.58 sq. km. of the total geographical area of the district. It lies between 26º 45' N to 27º 30' N latitude and 93 º 00’ E to 94 º 00’ E longitudes. It is bounded by Lower Subansiri district in the north-east, East Kameng district in the west and Assam state in the south.

Figure 1: Location



Literature Review:

Literature review has been made to reflect the salient aspects and development of the study. Different scholars from earlier days have carried out extensive studies on slopes and profiles till now. One of the pioneering works in the field of slope morphometry is that of A. Tylor (1875). In a paper far in advance of its time, he gave a valley side profile surveyed in detail; he plotted binomial curves that showed a close fit with observed slope form and he supposed that slopes are eroded into this curve because it is the 'form of greatest stability…. It is the form which gives the nearest possible approach to uniform motion of water on its surface.'

Hill slopes are the part of the landscape included between the crest of hills and their drainage lines. Chorley (1964) has given four difficulties associated with the study of slopes: their complexity of form, the multivariate nature of processes, the doctrinaire attitude of most researches, and the feedback nature of the problem. Many processes rather than a single one eg, lithology, surface and sub surface, flow of water, mass movements and base level are responsible for the forms of hill slopes, and in addition the evidence suggests that changes occur on slopes much more slowly than in stream channels (Leopold, et.al, 1964).

In mountainous areas orographic effects are pronounced with greater precipitation and rainfall also generally decreases eastward across the region (Abrahams, 1986). The coincidence of major storms, extensive logging or development on steep slopes, and major earthquakes could trigger major episodes of landsliding in the region. A rapid landslide poses the greatest hazard to life because they can destroy buildings or damage roads with little warning. Kockelman (1985) had outlined some techniques for reducing landslide like remapping of bedrock geology, preparation of regional slope- stability maps, mapping of soils overlying the landslides, land- use planners for the implementation of hazard-reduction programs and to engineers who serve as advisors to local or state governments.'

Slopes are the angular inclinations of terrain between hill tops (crests) and valley bottoms, resulting from the combinations of many causative factors like geological structure, climate, vegetation cover, drainage texture and frequency, dissection index, relative reliefs (and of course denudation processes, including weathering, mass wasting and mass movements of rock wastes, erosion and transportation of eroded materials down slope) etc. are significant geomorphic attributes in the study of landforms of a drainage basin.' Thus, slope is the upward or downward inclination of surface between hills and valleys and form most significant aspect of landscape assemblages (Singh & Srivastava, 1977). At the base level, foothills are originated because of active denudation mainly by rain wash, rill and gully erosion. These are minor slopes formed due to accumulation of debris/scree coming down from the hill slope as a result of mass movement of rock wastes (Chorley, 1985).

Geology:

According to Pilgrim (1910) and Pascoe (1919) the Siwalik formation is made of the river deposition. This river was extending along the foothills and called as 'Indo-brahm'. Siwaliks are 'fore deep' deposits. Streams flowing from the mountains in the north supplied huge amount of sediments to the foothills. Upper tertiary sequence has been grouped into three rock strategraphic units which are from bottom to top Dafla, Subansiri and Kimin formations roughly corresponding to the lower, middle and upper Siwalik of the central and western Himalaya.

Kimin formation is formed of alternate soft current bedded sandstone; siltstone, clay and gravel. Thickness of conglomerate ranges in between 3 m to 30 m. with clasts of pebble to boulder size. In the lower horizons the pebbles have an orientation parallel to the bedding. Upper horizons are having the random orientation. The clast material is composed of gneiss, quartzite, schist and vein quartzite. The sandstone are coarse grained loosely consolidated and having current bedding. Colour varies from gray, blue gray to orange brown. Carbonized wood fragments of the length ranging in between few cm to 2 m are seen during fieldwork.

Subansiri formation includes soft massive sandstone and commonly known as salt pepper sandstone. The sandstone is bluish gray in color, medium to coarse grained, massive, soft and poorly micaceous. On weathering they turn yellow brown in color. The rocks are current bedded and thickness ranging from a few cm to 3 m. Occasionally, they are pebbly with pebbles of purple and gray quartzite. They also contain carbonized and silicified wood fragments. In the study area these rocks are exposed along the ridge of Simna Parbat hills. This range is forming an anticline and in its north and south Kimin formation is present.

Dafla formation covers the altemative beddings of indurated sandstone and shale. These sandstones are light gray to brown in color and poorly micaceous. The clays are greenish grey in color, exhibit spheroidal weathering and thickness ranges from 1 to 5 cm. Greenish gray to dark gray thin shale bands normally form the base of these shales.

Temperature:

In general the rise of elevation decreases temperature; hence lower altitudinal areas have higher temperature, in the study area. Highest average temperature is 36º C (July), 32.5º C (July), 35º C (August), 36.4º C (July) and lowest temperature are 7º C (January), 9.7º C (December), 6.8º C (January), 8.5º C (January) at Itanagar center in the year 2002, 2003, 2004 and 2005, respectively.

Rainfall

The distribution of rainfall depends on slope aspects, altitude and alignment of ridges. The windward side receives more rainfall. In the study area, the maximum rainfall occurs in the months of September (823.7 mm), June (682.3 mm), July (797.2 mm), August (731.1 mm) and lowest rainfall are in the months of January (12.3 mm), January (22.3 mm), December (60.6 mm), December (0.6 mm) in the year 2002, 2003 2004 and 2005, respectively

Soil

In the study area, new alluvium is found which consists of recently deposited silt and sand and is rich in organic content and if it is less sandy it is very fertile and suitable for agriculture, this soil is generally rich in phosphate, potash, calcium, nitrogenous material and organic substances and is less acidic and not saline. The main problem is that, during heavy rainfall these soils are easily washed out before formation. The alluvial soil is sandy in the immediate riverbanks, loamy at some distance from the riverbeds and clayey in areas of greater distance from the river.

Data Base And Methodology

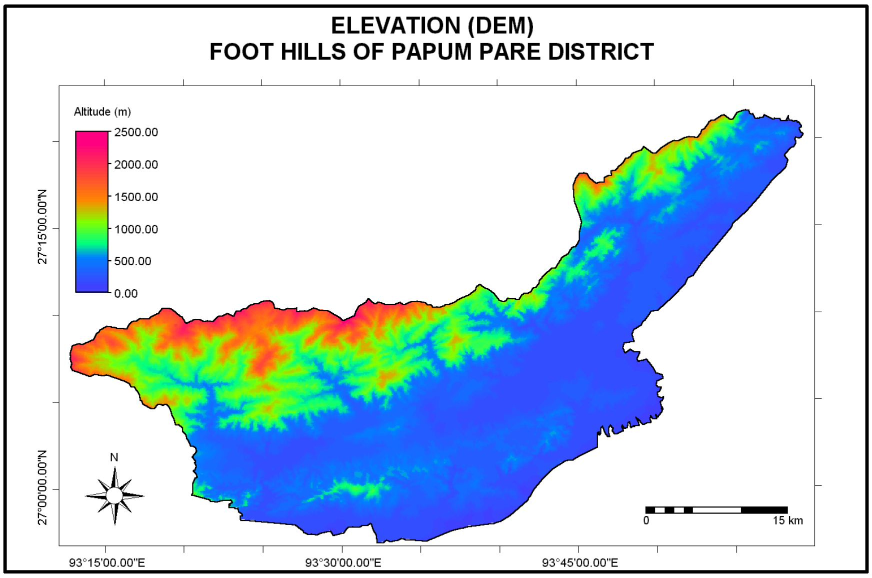
The study has been carried out using toposheets of SoI at 1:50000 scale, digital satellite data (LISS III) as source of spatial data base. Basic and preliminary information about different landforms have been collected from the topographical maps. Detailed field work has been done by taking traverse along the roads and rivers. The boundaries of different landforms units were delimited and salient erosional and depositional geomorphic features of each unit were identified. Various thematic maps have been prepared, for example, relief maps, drainage maps, slope maps and profiles, etc. An appropriate base map, contour map and drainage map would be prepared by using SOI topographical map. DEM, altitude map, aspect map, slope map, drainage density map (for morphometric analysis) have been prepared by using GIS method, ILWIS software from toposheets.

Relief And Slope Analysis

Digital Elevation Model (Dem):

Digital Elevation with a cell size of 100 m has been prepared for the study area using ILWIS software. The contour with an interval of 20 m has been taken as input. This DEM shows gradual altitudinal variation. The upper or the northern sides have higher elevation while the lower elevation prevails towards the southern side. The altitude ranges from 80 m to above 2275 m. Figure 2 and Table no.1 clearly shows that maximum area is covered by the lower elevations from 200 m to 500 m of about 60% of the total area.

Figure 2: Digital Elevation Model



Altitude Zone:

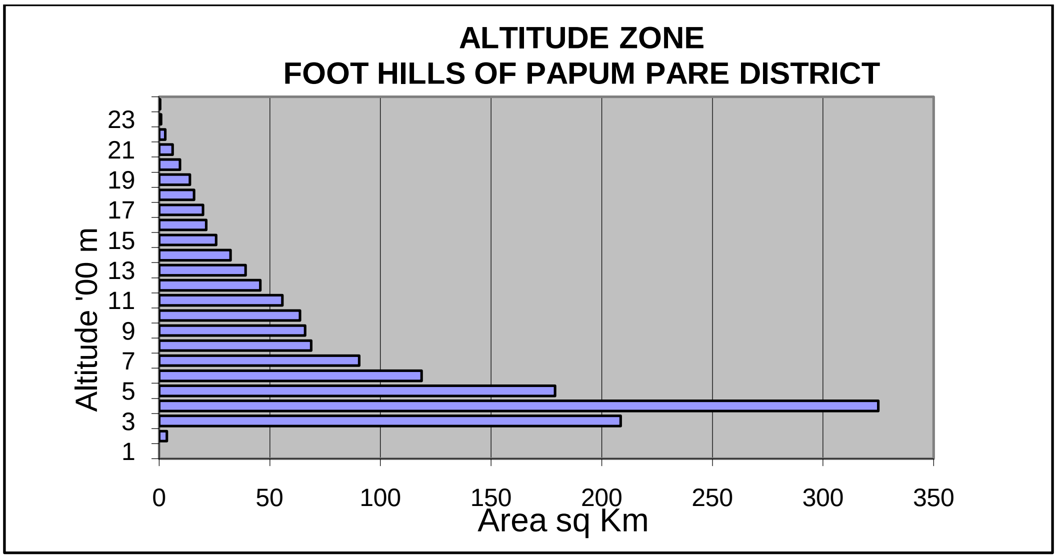
For a clear observation of the altitude zone of the area, a bar graph is prepared. Longer the bar of the altitude class higher the area covered by that altitudinal zone. Thus, figure no.3 shows that maximum area is under the elevation of 300 m to 500 m above sea level.

Table no. 1 **Altitude Zone and Area**

ALTITUDE	AREA Km
80	0.00
100	3.48
200	208.53
300	324.97
400	178.97
500	118.57
600	90.42
700	68.74
800	65.96
1200	39.08
1300	32.23
1400	25.77
1500	21.19
1600	19.86
1700	15.74
1800	13.82
1900	9.33
2000	6.08

900	63.60	2100	2.70
1000	55.68	2200	0.84
1100	45.65	2275	0.37

Figure no. 3: Altitude Zone



Slope Analysis:

There are different methods suggested by many earth scientist for the study of average slope. But here by using ILWIS software, the contour lines are digitized at 1:50 000 scale with 20 m interval. Plan slope is calculated using interpolation technique and further classified into six slope categories such as flat, plain, moderate, steep, very steep and precipitous. Table no 2 and Figure no. 4 clearly indicates the six categories of slope with their area and broad classification.

Figure No. 4 Slope

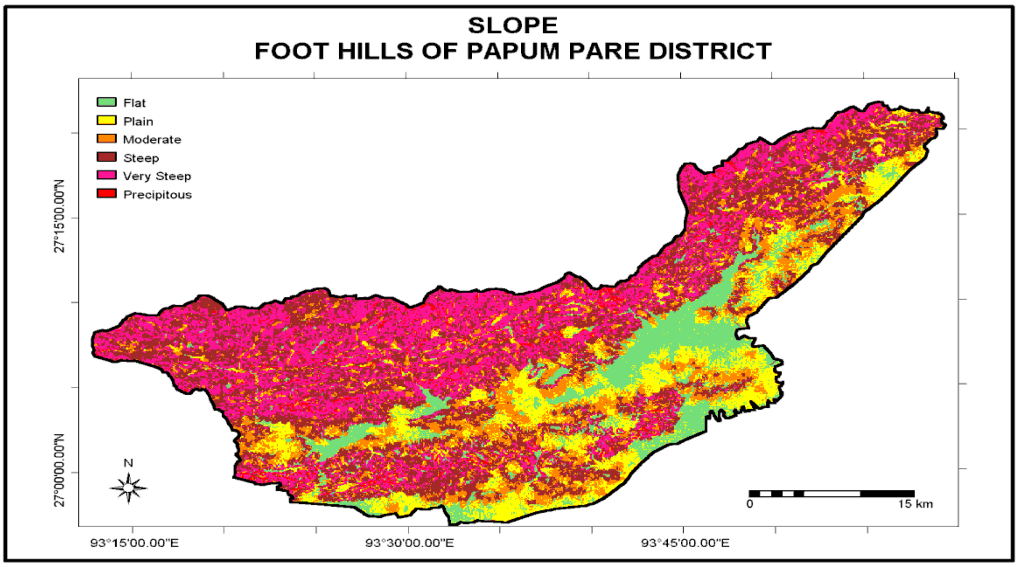


Table no. 2: Average Slope

Sl. No.	Slope Classes	Slope category	Area (in sq.km)	Area (in%)	Cumulative area (in%)
1	Below 2º	Flat	181.80	12.88	12.88
2	2º-5º	Plain	199.92	14.16	27.04
3	5º-10º	Moderate	208.16	14.75	41.79
4	10º-25º	Steep	426.47	30.21	72.00
5	25º-45º	Very steep	358.32	25.38	97.38
6	45º and above	Precipitous	36.91	2.62	100.00

Aspect:

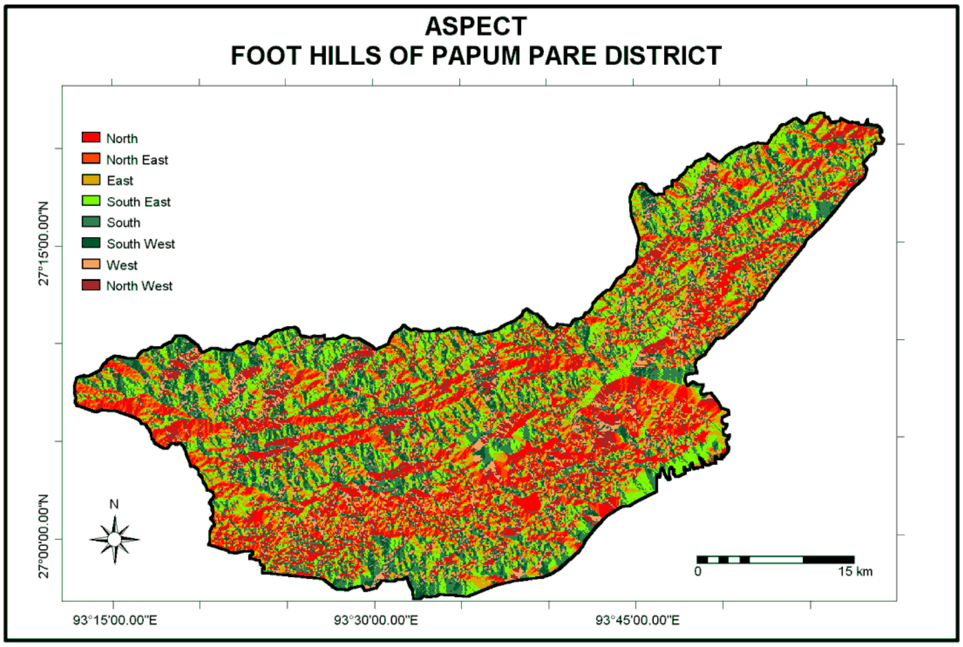
The ground slope facing the sun receives more insolation because the sun's rays reach the surface more or less straight an hence sun facing ground surfaces record higher temperature than the leeward slopes where sun's rays reach more obliquely. Thus, sunshine plays an important role in the growth of settlement and cultivation. Number of sunny days, duration of sunshine and its intensity plays a determining role. So aspect study of the area is an integral part of the study. The aspect analysis shows the presence of sunlight called as *ubec*. The possibility of vegetation cover is also found to be more in the sunny side of the terrain. Topography affects the absorbance of solar energy in a given landscape. In the northern hemisphere, south facing slopes are more perpendicular to the sun's rays and are generally warmer and thereby commonly lower in moisture than their northern facing contour part. Thus the sunny side of the aspect supports dense vegetation cover as well as agriculture.

Aspect map (figure no 2.6) and Table no. 2.3 shows that from south east to south i.e. from 112.5º to 202.5º, there is more chance of vegetation cover, agriculture and settlement, followed by north direction i.e. from 337.5º to 22.5º.

Table no. 3 Aspect

Sl. No.	Degree	Category	Area (in sq.km.)	Area (in %)	Cumulative Area (in %)
1	337.5-22.5	North	210.89	14.94	14.94
2	22.5-67.5	North east	133.88	9.48	24.42
3	67.5-112.5	East	181.10	12.83	37.25
4	112.5-157.5	South east	236.47	16.75	54.00
5	157.5-202.5	South	236.73	16.77	70.77
6	202.5-247.5	South west	151.67	10.74	81.51
7	247.5-292.5	West	131.88	9.35	90.86
8	292.5-337.5	North west	128.96	9.14	100.00

Figure: 5: Aspect



GEOMORPHIC UNITS AND ASSOCIATED LANDFORMS:

On the basis of detail study of the satellite images, altitude zone, hypsometric integral, physiography, slope, aspect maps and a limited fieldwork an attempt has been made to delineate the study area into homogenous geomorphic units for which different units are identified

ALLUVIAL PLAIN –Alluvial plains are formed when the transporting capacity of the streams decrease enormously at the foothill zones while they leave the mountains and enter the plain topography because of substantial decrease in their velocity consequent upon decrease in channel gradient and finally deposited some materials consisting of finer to coarser and big sized materials of the foothill zone. In this unit the height is between 70 m to 100 m, relative relief is from 0 to 100 m and slope ranges from level to 7º respectively.

PIEDMONT –Before reaching to the plain the tributaries of Papum, Pam, Buraii, Pachin, Niorch and Dikrong Rivers are making fan like formation of alluvial deposit. This area is called piedmont because all the individual fan boundaries are intermingled and it is very difficult to differentiate. This unit is made of mainly boulders, cobbles, pebbles, gravels, sand and silt. The height of this unit is between 100 m to 300 m, relative relief is from 20 to 100 m and slope ranges between 7º to 14º respectively.

HIGHLY DISSECTED LOW HILLS –Drainage density is very high in this area and a small stream is also having a gully type channels. This unit has weaker rocks due to which erosion is very high. It comprises of conglomerates and loose sandstones. The height of this unit is between 100 m to 300 m, relative relief is between 100 m to 200 m and slope is from 14º to 21º.

LOW RELIEF RUGGED HILLS – An area having uneven topography, high drainage density, dendritic drainage pattern, gentle gradient streams and gullies with wide open V-shaped valleys is named as low relief rugged hills. It comprises of poorly consolidated alternate sand, clay and conglomerate. This area is found to be more or less like bed land topography. Small streams also have a wide valley and watersheds in between are narrow. This area is extending in the north of Simna Parbat anticline. Probably the area comprises synclinal limb. In this unit the height is between 600 m to 1000 m, relative relief is from 100 m to 400 m and slope is from 14º to 29º respectively.

STRUCTURAL HILLS –The area which showing banded texture, straight ridge lines and a combination of parallel, rectangular and trellis drainage pattern is designated as structural hills. It is further divided into two zones i.e. low relief structural hills and high relief structural hills on the basis of altitude. In the low relief structural hills flat iron an scarps type of features are found and in the high relief structural hills rapids are found. In the low relief Structural hills the height ranges between 100 m to 600 m, relative relief is 200 m to 500 m and slope is from 21º to 28º respectively. In the high relief Structural hills, the height is between 1000 m to 1200 m, relative relief is between 200 m to 500 m and slope is between 21º to 35º respectively.

DENUDATIONAL HILL –This area appears more subdued and denudated so this is called as denudational hills. This area is older in age than the Siwalik so ridge lines are not so sharp as in the Siwalik lithology. Dendritic and radial type of drainage patterns are found in this area. this unit lies in the north of the study area. this unit has height between 1200 m to 2380 m, relative relief between 100 m to 800 m and slope is from 21º to 43º respectively.

During the Himalayan formation the tectonic activities form structural dislocation and deformation due to which various landforms are formed. Some of the major landforms are as follows –

HOGBACK –The escarpments or ridges having symmetrical slopes on both sides are called hogback ridges or simply Hogbacks. Hogbacks are formed due to faulting and thrusting which indicates the inner lying structural disturbances. A sudden break in topography due to higher side slope or anti –dip slope than the dip slope. In the study area it is generally followed by the lineaments.

GORGE –Very deep and narrow valleys having very steep valley side slopes say wall –like steep valley sides are called Gorges. In the study area small streams passing through the uppermost deposits i.e. loose sand and clay stone (Kimin formation and Post Siwalik deposits) comprise deep gorges. The depth of gorges in some places found upto 15 m. This kind of observation can be explained only proper understanding of the structural control on it. This kind of topography may be observed along the foothills and Jote-Basarnala-Yadang valley. On the basis of these observations it appears that upliftment during the recent years might have been higher.

RIVER TERRACE –The narrow flat surfaces on either side of the valley floor are called river terraces which represent the level of former valley floors and the remnants of former flood plains. River terraces are generally formed due to dissection of fluvial sediments of flood plains deposited along a valley floor. River terraces are found in a corridor along the Dikrong and Pachin River. The thickness of the terraces varies from point to point. The forming material includes sand, sand with pebbles, sand with earthy clay, loose sand with very small pebbles, big boulders with sand and pebbles. The shape of these pebbles varies from elongated, semi-rounded, sub rounded to sub angular and made of quartzite, gneiss, schist and few of slate. In general the maximum pebbles are made of quartzite. Four level terraces are identified along Itanagar-Jote-Basarnala and Yadang.

CHANNEL BAR –Channel bars are formed due to the change in the gradient on the way of river channel. Channel bars are found in this area due to the tectonic activeness of foothill thrust. Channel bars are observed along the Buraii, Papum, Pachin and Dikrong Rivers.

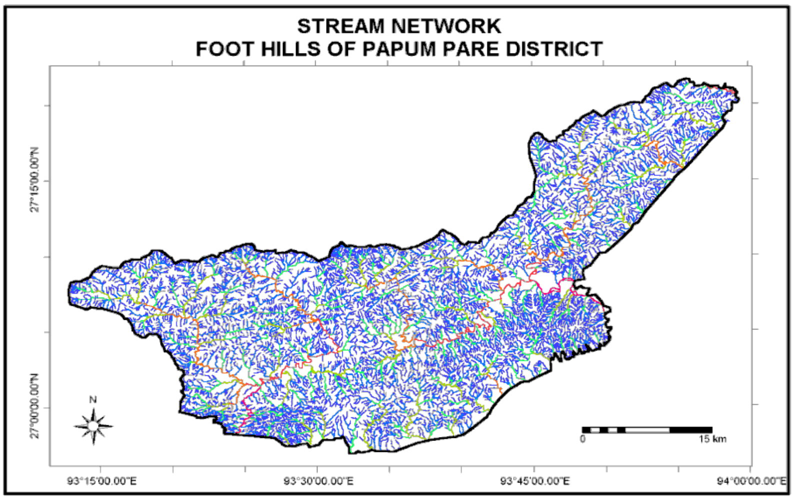
VALLEY FILLS –The valley fills are in different pockets scattered over the Pachin and Papum river basins. A large amount of sediment brought by the streams descending from the highly dissected low hills. These valley fills are comparatively plain areas best suited for agricultural purposes.

DRAINAGE ANALYSIS

DRAINAGE NETWORK

In the study area, the main river is Dikrong, which flows from north-west to south east and joined by its various tributaries. The main tributaries are Papum, Pam, Pachin, Senkhi, Singra, etc. These rivers are mostly seasonal in nature. The drainage network is following the regional sloped in the direction of north, south east to south and well adjusted to geological structure, joining the river Brahmaputra near Ramghat. In the present study the streams of river basin of the circle have been ranked according to Strahler's stream ordering system. Thus, the Dikrong River, which is the trunk stream of the study area, is of the 7th order. Its tributaries are of lower orders (figure no.6)

Figure No. 6 Drainage Network



Drainage Density

Drainage density of the area has been derived using digitized drainage map at 1:50000 scale and segment density technique available in ILWIS, with cell size of 500 m.

Dd = ∑L / A

Where, Dd = Drainage density

∑L = Total length of stream in the grid/cell

A = Total area of the cell

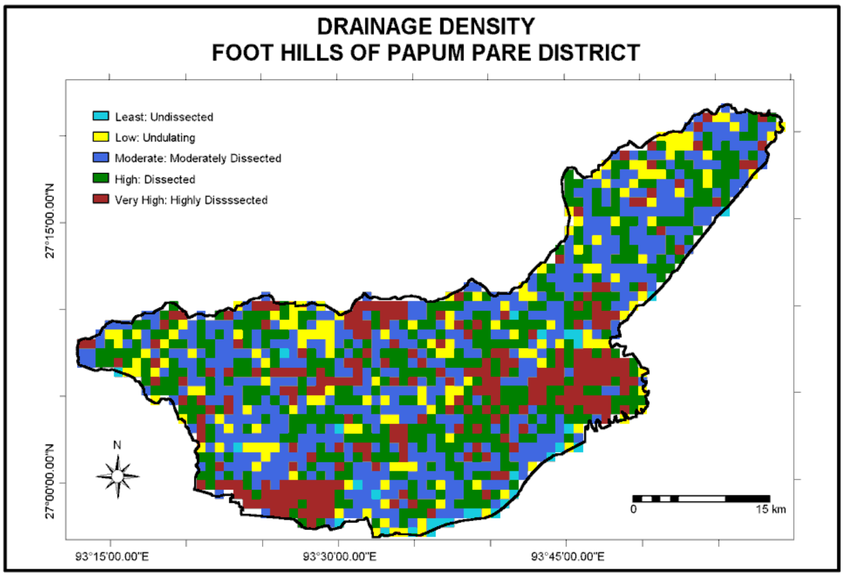
Selecting a suitable class interval, five indices of dissection ranges i.e. Undissected, Undulating, Moderately dissected, Dissected and Highly dissected were formulated (Table 4)

Table no. 4 Drainage Density

Sl. no.	Drainage Class (in m/grid)	Category	Area (in sq. km.)	Area (in %)	Cumulative area (in %)
1	Below 1000	Undissected	31	2.13	2.13
2	1000-2000	Undulating	168	11.94	14.07
3	2000-3000	Moderately dissected	519	36.75	50.82
4	3000-4000	Dissected	439	31.20	82.02

5	Above 4000	Highly Dissected	254	17.98	100.00
		Total Area	1411		

Figure 7: Drainage Density



Summary and Conclusion:

Regional variation in slopes in the area is associated with tectonic movement with high degree of denudational activity besides other factors such as weathering, process of erosion, transportation. Average relief in different categories expresses the intensity of relief, which can be determined per unit area. In the study area maximum area is under the lower altitudinal zone, a little area is under the higher altitudinal zone and the moderate intensity almost scattered around the central portion of the area.

The slope, aspect and physiography map of the area expresses the amount of slope and nature of the surface slope. The highest relative relief is found in the northern and north western parts, showing structural hills of slightly dissected topography. Moderate relative relief is scattered in the eastern, western and central part of the area with dissected topography. The lowest relative relief is in the southern part of the area with highly dissected topography. This may be due to the higher elevation area has made up of hard rocks and the lower elevation are of softer rocks.

Five categories such as undissected, undulating, moderately dissected; dissected and highly dissected types of drainage density are defined from the length of stream with reference to its intervening spaces which vary in degrees. It coincides with rate of erosion and degradation land in the area. An attempt has been made to classify landforms on the basis of comparison of the results of different morphological techniques applied to the study area. Some of the geomorphic units are alluvial plain, piedmont, highly dissected low hills, low relief rugged hills, structural hills, denudational hill and the associated landforms are hogbacks, gorges, landslides, river terraces, drainage, boulders, channel bars, river meanders, fault scarp, valley fills, etc.

Overall analysis indicates the rock types and structure especially in the Siwalik region control the Geomorphological characteristics of each identified Geomorphological units. In the satellite image dissection pattern is clearly distinct and highly influenced by the litho logy of the area. Major impact of structure or drainage pattern especially in between Main Boundary Fault and Tipi Thrust can be delineated from topographical maps, satellite images, and FCCs.

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